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ELECTRODES FOR CONTINUOUSLY MEASURING COTTON MOISTURE CONTENT AT GINNERIES

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ELECTRODES FOR CONTINUOUSLY MEASURING COTTON MOISTURE CONTENT AT GINNERIES

By Gino J. Mangialardi, Jr., and A. Clyde Griffin, Jr.[1]

INTRODUCTION

Research by the U.S. Department of Agriculture Cotton Ginning Research Laboratories has shown that cotton fibers more nearly maintain their inherent length properties when ginned at relatively high-moisture levels rather than at low-moisture levels. If the moisture content is too high, on the other hand, cleaning efficiency is lowered, mechanical operation of the machinery becomes difficult, if not impossible, and the ginned lint is characterized by poor preparation.

Research relating fiber quality to moisture content almost invariably shows that a fiber moisture content between 6.5 and 8 percent generally provides smooth ginning and satisfactorily preserves cotton quality. For this reason the applied research activity of the Federal Cotton Ginning Research Laboratories directed toward developing an automatic moisture control system for cotton ginneries has used the 7 to 7.5 percent moisture range as the design center for the system.

Public gins used commercially available controls to dry high-moisture cottons. A few gins have installed moisture addition equipment that is manually controlled to raise the moisture content of low-moisture cottons. During the 1966 crop year, the U.S. Cotton Ginning Research Laboratory demonstrated a moisture-control system which automatically either removed or added moisture, as required by the cotton entering the gin plant.[2]

One major component of a moisture-control system is the moisture-measuring subsystem. This subsystem, as used in most gins, is based upon the relationship between electrical resistance and moisture content. The moisture detector measures the electrical resistance of seed cotton passing between two electrodes, and reports the measurement as moisture content percentage.

Two types of electrodes currently employed at ginneries are: (1) A flat metal plate located in the master feed control hopper to measure electrical resistance of seed cotton between the plate and hopper walls, and (2) feed rollers located between the distributor and extractor-feeder to measure electrical resistance of seed cotton passing between them.

Experimental data have shown that in addition to variation in cotton moisture content, the magnitude of the measured electrical resistance was significantly affected by parameters that included (1) electrode area, (2) seed cotton density, and (3) electrical leakage between the electrodes.

This report presents a record of the electrode research performed at the Stoneville Laboratory. It describes the types of electrodes investigated, lists advantages and disadvantages of each, and gives recommendations for their design and maintenance.

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[1] Research agricultural engineer and research physicist, respectively, Agricultural Engineering Research Division, Agricultural Research Service, U.S. Department of Agriculture, U.S. Cotton Ginning Research Laboratory, Stoneville, Miss.

[2] Griffin, Clyde, Jr., and Mangialardi, Gino J., Jr. Another First–A Completely Integrated Moisture Control System for Gins. The Cotton Gin and Oil Mill Press, June 3, 1967.

EARLY EXPERIMENTS

Moisture Measurements at Lint Slide With Spot Test Instruments, 1953-54

Before experiments were conducted on the continuous measurement of cotton moisture content, moisture readings were obtained using spot test instruments. The instruments (portable, battery operated) used the electrical resistance measuring principle and were especially designed to determine the moisture content of lint cotton.

Two lint moisture meters were obtained by the Laboratory during 1953 and 1954 from different manufacturers. The meters were evaluated for accuracy by comparison with oven method moisture determinations.[3] Both meters utilized a spring-loaded electrode cup for holding a small unweighed lint sample. One meter also had a special two-prong 8 1/4-inch accessory electrode to insert into pressed bales to determine the moisture content of baled cotton. The instruments were simple to operate and from 3 to 5 moisture measurements could be made per minute.

These experiments and others during 1955 showed that the instruments were fairly accurate in the lower moisture range, but differed from the oven values by about 1 percent in the higher range. However, one instrument indicated that it could be calibrated to within one-half percentage point for moisture content between 4 and 11 percent.

The experiments pointed out that (1) 5 or more readings should be made with the meter and the results averaged to give a reliable estimate of moisture content, and (2) the operator should wear gloves to prevent error in the results due to moisture absorbed from his hands.

Thin Brass Floating Electrodes on Pilot Gin

The first continuous measurement of cotton moisture content was conducted on the 1954 crop. Using one of the portable battery-operated meters, measurements were obtained with two brass rollers replacing the sample cup (fig. 1). The rollers were located behind a 20-saw gin and continuously received lint in batt form as rapidly as it was ginned for moisture measurement.

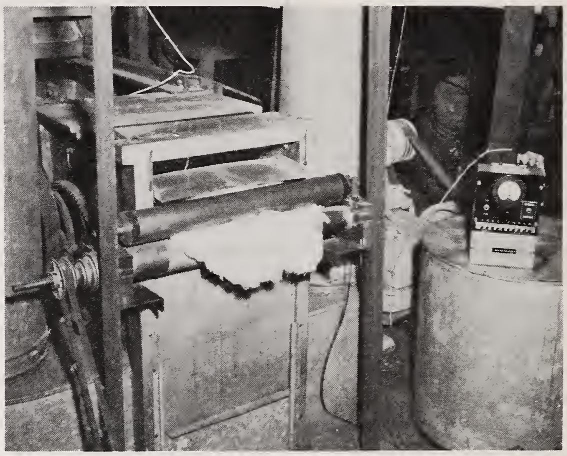

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Figure 1.—Brass rollers and moisture meter as used for continuously indicating moisture content of lint concurrently with ginning, 1954 crop.

Work with these electrodes showed that the peripheral speed of the rollers must be matched to the velocity of the batt to prevent tearing the batt or choking the rollers. The surface of one roller was knurled in an effort to overcome a tendency for very dry cotton (below 4 percent) to slip at the rollers instead of feeding through. The indicating needle of the meter oscillated widely with very dry cottons but remained relatively stationary on damper cottons. Later experiments showed that static electricity on the cotton caused this erratic movement on low-moisture cotton.

Driven Electrodes

Experiments on the continuous measurement of lint moisture content were conducted from 1955 to 1957. An electrically operated resistance meter was connected to two rotating cylindrical electrodes. These electrodes were located on the discharge side of the lint condenser at the lint slide and were so arranged that the lint batt passed between them. Both were chain driven at a peripheral speed equal to that of the condenser drum. One of these was a

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[3] American Society for Testing and Materials. Tentative Method of Test for Moisture in Cotton (Oven-Drying Method). 1968 Book of ASTM Standards, pt. 25, pp. 543-549. October 1968.

continuous aluminum roller in a fixed mount while the other was attached to pivot arms so that its weight applied a continuous and constant pressure to the lint batt. The fixed electrode was grounded electrically; the pivoted electrode was insulated from the ground by plastic-bearing blocks and will be referred to as the measuring electrode. Two measuring electrode configurations were designed, fabricated, and tested.

6-Inch-Wide Electrode

The first electrode was a 6-inch length of aluminum pipe located at the center of the lint batt (fig. 2). During testing two principal faults were found with this electrode. First, the lint batt was in contact not only along the 6-inch surface, but because of fluffing, it also contacted the sides of the electrode so that the effective electrode width was inconstant. This varying width was judged responsible for the wide differences between moisture content measured by the rotating cylindrical electrodes and that determined by the oven method.

E-2948

Figure 2.—Single 6-inch aluminum electrode used in continuous measurement of lint moisture content, 1955-57. Note fluffing of batt against sides of the electrode.

The other fault was the tendency of fluffs of cotton to wind themselves about the electrode shaft, thereby creating leakage paths that affected the meter readings as they contacted the lint batt.

Three Band Electrode on Wooden Roller

The measuring electrode that was next tried was a built-up wooden roller with three 2-inch-wide aluminum bands recessed and set flush with the roller surface (fig. 3). One band was in the center of the roller and the other two were located 13.5 inches from the center, one on either side. These bands were wired to a collector ring at one end of the roller. Data collected using this electrode showed much less scatter than that collected using the 6-inch electrode.

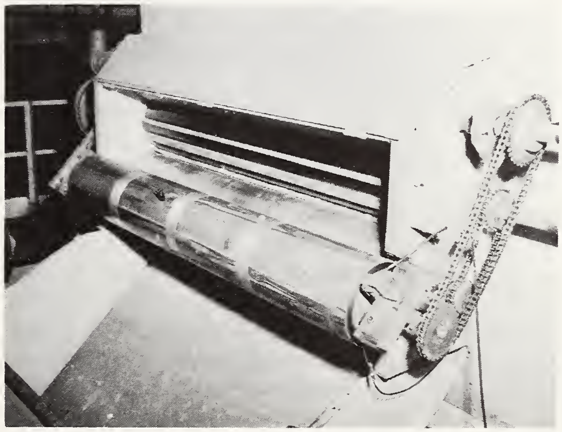

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Figure 3.—Wooden roller with three 2-inch band electrodes used for continuous measurement of lint moisture content, 1955-57.

The data showed that the correlation between recorded moisture and oven moisture was as good with one band in use as with two or three when there was a full batt. The number of working bands, however, did make a difference with less than a full batt. An improper response was caused when there was no cotton in the proper place to give a signal. Also, an incorrect low reading was obtained when the first wisps of cotton were passing between the electrodes, and again at the end of ginning when the last wisps were passing through.

SEED COTTON MOISTURE MEASUREMENT

One series of tests was conducted in 1955 to ascertain whether the meter could be adapted to indicate the fiber moisture content of seed cotton without removing the seeds. A special deep plastic cup and hydraulic press were constructed so that the same equipment could be used for both lint and seed cotton. Experiments with this equipment using lint showed that meter indications would vary for various hydraulic pressures. Measurements also varied with sample size.

The study showed that when measuring very dry cotton the seeds were electrically inert so that 25 grams (g.) of lint and 75 g. of seed cotton showed identical fiber moisture content with the deep cup and meter. At higher moisture levels, the seed tended to short circuit the fiber so that the deviation between lint and seed cotton moisture measurements increased as seed moisture content increased. These data did indicate, however, that the electronic gaging of fiber moisture content of seed cotton might be sufficiently accurate for practical gin application.

Electrode Types, 1958

Experiments were conducted during 1958 to obtain calibration curves for fiber moisture content of seed cotton using a laboratory developed detector-recorder unit with two pairs of rotating electrodes. The electrical signal obtained by passing undried seed cotton between one pair of electrodes was recorded and compared with the electrical signal obtained by passing the same cotton after drying between a second pair of electrodes. The electrodes were located in collecting hoppers or surge bins. Although decreases in fiber moisture content were measured and recorded, the experiments were abandoned because of mechanical difficulty in maintaining the proper balance in the flow rate of seed cotton between the feeding and receiving hoppers.

Rod Electrodes, 1959

Rod electrodes were investigated in 1959. These electrodes were made of brass rods 1/8 inch in diameter and of various lengths. They protruded into the feed hopper from plastic insulators installed on the hopper wall. The electrical resistance of cotton was measured between the rods and the grounded hopper wall. The tests showed that the measured resistance varied as the length of the electrode and cotton density varied (appendix table 1). Normal operation of the seed cotton automatic feed unit necessarily causes variation in the quantity of cotton in the hopper and thereby causes variations in density at the rod electrodes.

The rods tended to break off during actual ginning and enter the cotton stream.

Feed Roller Electrodes in Master Feeder Hopper

In 1958 experiments were started in the Laboratory's three-stand commercial-type gin using feed rollers as moisture-sensing electrodes.

The rollers were standard star-shaped 48-inch feed rollers and were located in the master feed control hopper (fig. 4). One electrode was insulated from the hopper and drive mechanism with acrylic-plastic (plexiglass) mounts and the electrical signal was collected from an insulated bronze bearing within which the shaft rotated. The other electrode was grounded electrically and not insulated.

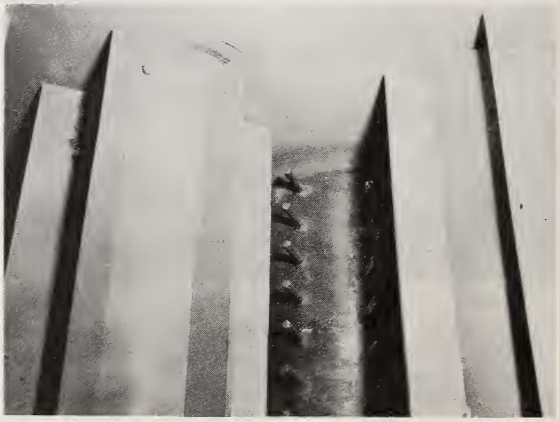

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Figure 4.—Star-shaped electrodes employed in the master feeder hopper, 1958-62.

These rotating electrodes were under heavy spring tension to provide constant pressure on the cotton passing between them and thereby giving more reproducible moisture measurement. No noticeable movement of electrodes was observed when seed cotton was fed between them.

The electrodes were connected to the recorder unit about 20 feet away. High-quality, vinyl-insulated copper wire was used as the "hot" or signal lead. The grounded electrode was connected indirectly to the moisture-measuring unit through the structural steel of the building.

During 1960, these electrodes were tested with a resistance-measuring detector and recorder. Samples of cotton were taken just before the cotton passed between the electrodes, for immediate ginning on an 8-saw gin and were canned for oven determinations of fiber moisture. The recording chart was marked at the time samples were taken to provide a basis for calibration.

The measured resistance of these lots followed the general shape of the natural cotton moisture calibration curve (fig. 5).

This curve, obtained by plotting oven-determined fiber moisture content versus automatic detector output, is considered typical of the resistance type of moisture detector response. Scatter of individual points about the fitted curve was considered to arise from several sources:

1. Uneven distribution of moisture within the seed cotton mass;
2. Quantity and moisture content of plant parts (such as leaves, hulls, and stems) mingled with seed cotton;
3. Moisture content of the cottonseed;
4. The effect of residual production and harvesting agricultural chemicals; and
5. Errors in sampling and moisture determinations.

Numbers 1 and 2 are the most prevalent of these sources and the most difficult to compensate for. Number 3 may be considered a constant, varying with time of harvest and prevailing weather. Number 4 was of only minor importance, and number 5 may be minimized by adequate sampling.

The fitted curve was considered to be an operating curve for automatic drying control and was used to select operating points for a selectable path drier.

One problem encountered with the star-shaped electrode was fiber lodging between electrode ends and the feed control hopper wall. This had the effect of indicating the presence of cotton when no cotton was in the hopper. Also, if the lodged fiber was at a higher moisture content than that of the cotton being processed, it would call for greater drying than actually required and would result in overdrying the cotton.

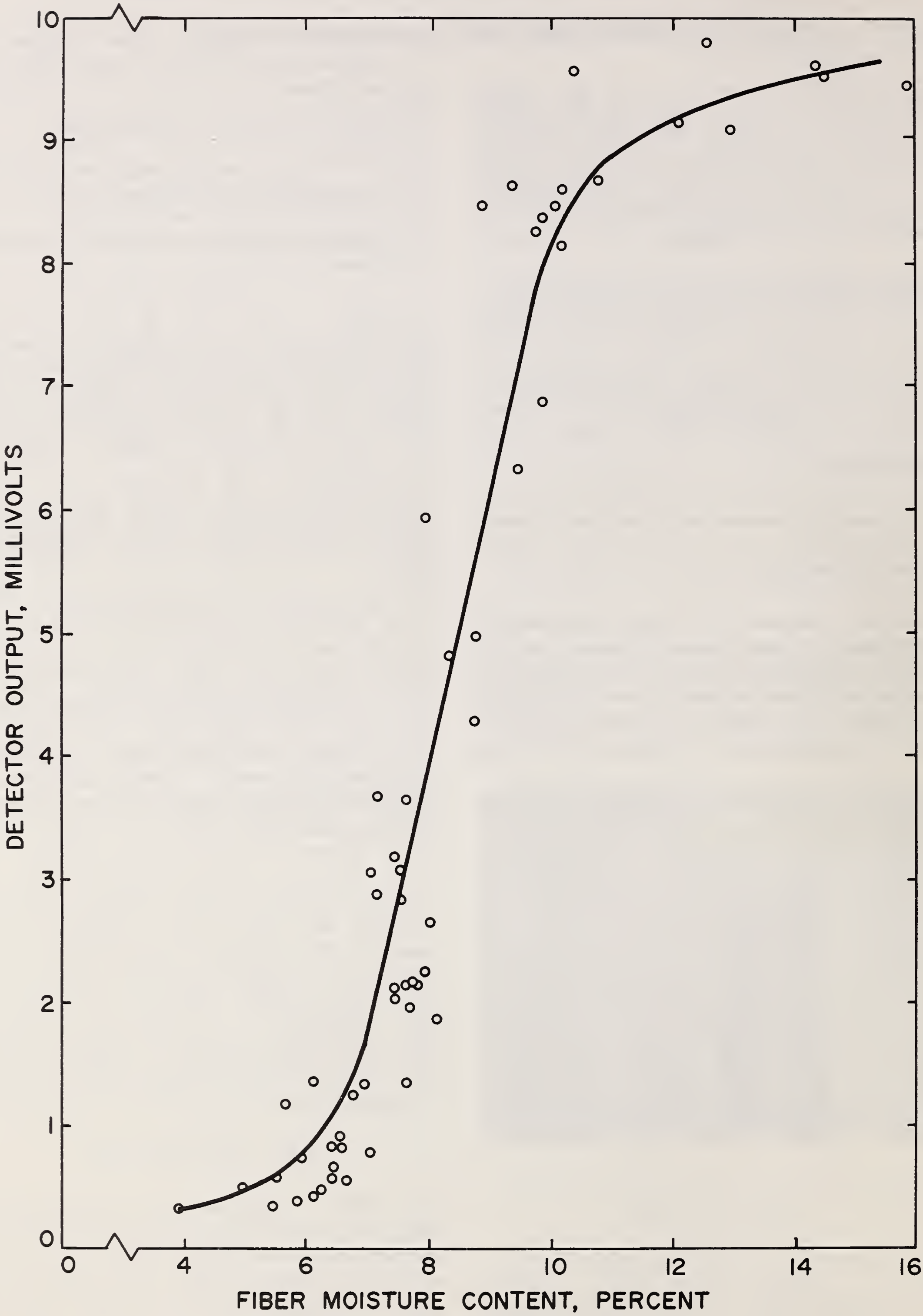


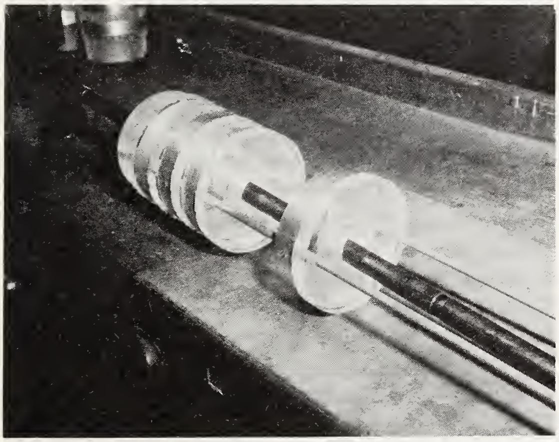
Figure 5.—Moisture detector output as a function of fiber moisture content, 1960 experiments.

PARALLEL BAND ELECTRODE DEVELOPMENT

Electrode Design, 1960

The use of standard feed rollers as measuring electrodes posed the problems of insulating the signal electrode from the hopper itself and keeping the clearance between electrode ends and the hopper walls free of trash and cotton that tended to wedge and cause unwanted signal paths.

The idea of using parallel band electrodes set in a plastic core on a single shaft to eliminate the necessity of insulating feed roller shafts from the hopper led to the design and fabrication of a parallel-band electrode in 1960 (fig. 6). It was tested in early 1961.

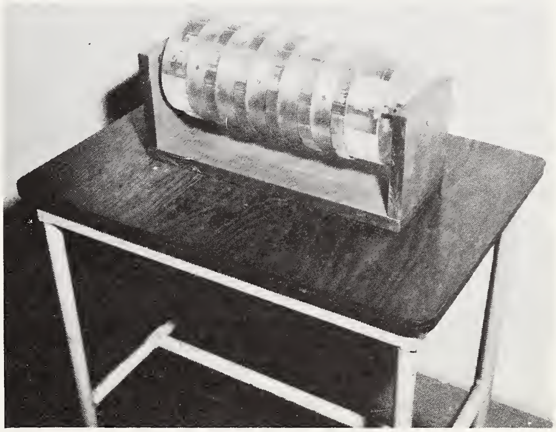


E-3499

Figure 6.—Construction of a multiband electrode on acrylic plastic discs. designed in 1960.

The concept of alternately connected parallel bands on an acrylic core as electrodes for measuring cotton moisture in gins is sound. The spacing between bands can be made smaller than the gap between opposed rotating electrodes with a consequent theoretical increase in usable signal. However, the bands should not be so close as to provide short circuits caused by cotton boll hulls bridging the insulating part of the assembly. Grass, sticks, limbs, and green leaves may be almost any length or size and should not influence the spacing of the band.

The electrode section developed for measuring seed cotton fiber moisture (fig. 7) was fitted into the center section of a feeder roller. The electrical path length was held absolutely constant because resistance was measured between adjacent 1.25-inch bands set 0.75 inch apart. A second rotating surface was required to provide a bearing surface for the banded electrode to work against to maintain a relatively constant pressure on cotton passing between them.



E-4182

Figure 7.—U.S. Department of Agriculture's multiband electrode developed for measuring seed cotton moisture.

Five bands were used for measuring seed cotton moisture—two were at ground potential and the other three served as the signal or hot electrodes. The ground potential bands were connected to the shaft which in turn connected to the building frame. The signal electrode bands were electrically connected to an insulated bronze fitting at the end of the roller shaft where the signal was collected with a carbon brush assembly. The signal was carried from bands to fitting by high-quality, vinyl-insulated copper wire passing through a hole bored in the roller shaft.

A second multiband electrode was also constructed for use at the lint slide. However, a greater number of bands were used at this station (fig. 8) to insure that measurements could be made even when the batt did not extend over the entire width of the lint condenser. A uniform fiber batt density was maintained by the weight of a floating roller and, again, the electrode surface speed was matched to that of the condenser.

Experiments with the parallel electrode system showed that it was suitable for use in an automatic moisture control system. The experiments also showed that a counter-rotating roller working in conjunction with the signal electrode was required for improving the mechanical operation and flow of seed cotton.

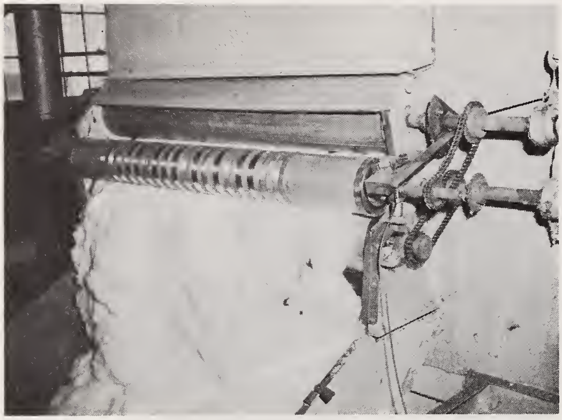


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Figure 8.—Multiband electrode developed for fiber moisture determinations at the lint slide.

Electrode Comparison Experiments, 1965

Experiments and investigations were conducted during 1965 to evaluate and compare the multiband electrode with other types of electrodes that are used in commercial gins for measuring and controlling moisture. The experimental design provided for adjusting and measuring the density and the electrical resistance of seed cotton while testing these electrodes.

Electrodes studied were:

1. A flat bronze plate, 1.75 inches by 2 inches (3.5 square inches), located in the master feed control hopper and insulated from the hopper wall by a 0.25-inch plexiglass plate, 3 inches long and 2.75 inches wide.
2. Conventional flow rate control feed rollers, one roller electrically grounded with Teflon bearings. The rollers were 5 inches in diameter, star-shaped, and 24 inches long.
3. The Department's multiband electrode system, located below the feed rollers.

The electrode system was 6 inches in diameter and consisted of 5 aluminum bands 1.25 inches wide, separated by 0.75-inch-wide Lucite spacers. Three alternate bands were electrically wired together and formed the signal or "hot" electrode, and the other two bands were connected together and were at ground potential. A spring-loaded pressure plate rode against the 5-band electrode to adjust plate-to-electrode pressure, for regulating the density of the cotton for the resistance measurements.

Cotton resistance measurements were automatically made by a detecting circuit working into a strip chart recorder.

Before the resistance measurement tests on seed cotton, the electrode-detector-recorder combination was calibrated, with precision resistors applied across the measuring circuit. This produced a resistance calibration of the system corresponding to the 100 divisions of the chart.

Machine-harvested cotton was then divided into fifteen 50-pound test lots and these lots were subjected to varying ambient relative humidities to provide cotton at a range of moisture levels normally encountered in a commercial cotton gin. Lots were fed through the electrode system only when preselected target moisture levels were reached. A portable electronic moisture meter served as a guide in estimating these levels. The actual moisture content of the samples was established by oven determinations of lint ginned on a small laboratory gin concurrently with the electrode measurements. The 15 lots were found to cover a fiber moisture range of from 4.5 to 17.4 percent.

Before feeding the seed cotton through the electrode system, the entire 50-pound test lot was placed in the 5-foot hopper (distance from feed rollers to top of bin). This quantity of cotton filled the hopper evenly without packing. The hopper cross section was 15.5 inches wide, with a 24-inch length, and produced an average seed cotton density of 3.87 pounds per cubic foot.

During the experiment, the master feed rollers turned at 2 revolutions per minute (r.p.m.) and fed seed cotton at a rate of 3.36 pounds per foot of length per minute. The multiband electrode roller rotated at a speed of 1.67 r.p.m. which corresponded to the surface speed of the feed rollers.

Actual instrument responses for the three types of electrodes are shown in figure 9. Resistance readings in scale divisions are shown for the test lots containing 6.3, 6.7, and 9.0 percent fiber moisture content. Readings obtained with the wallplate electrode are shown at the lower part of the chart, the feeder electrode at the center, and the multiband electrode at the top. Readings for the multiband electrode are shown for 6, 8, 16, 26, and 40 pounds of spring pressure from the bottom to the top of the chart, respectively. The study showed that the practical electrical resistance of cotton normally encountered at a gin plant varies from 30,000 ohms to 1,000 megohms.

Wallplate Electrode

When the wallplate was used as the signal electrode, seed cotton resistance was measured between the plate and the hopper wall which was at ground potential. Seed cotton pressure against the plate dropped from approximately 0.12 pounds per square inch (p.s.i.) to zero while seed cotton was fed through the 4.5-foot height. Seed cotton bridged twice during the trials with no seed cotton against the plate; this condition drove the recorder pen to maximum resistance. This position would be interpreted by the controller as due to very dry cotton and in practice would set the drying conditions for minimum or no drying.

The effect of changing depth of cotton as it passed through the feed rollers caused changes in seed cotton density that created changes in instrument response although the moisture content of the cotton did not change. Appendix table 2 shows considerable scatter resulting from changing depth from 4.5 feet to 1 foot above the electrode.

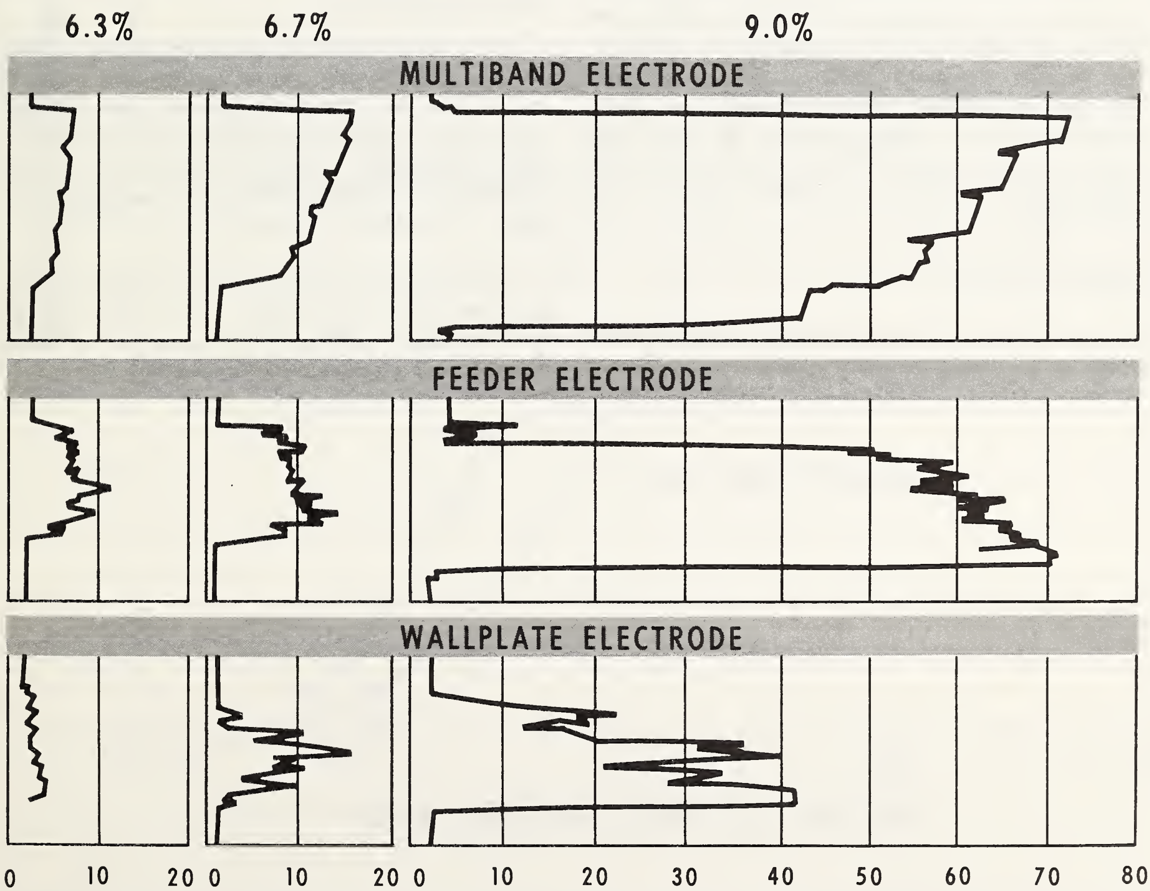

Figure 9.—Instrument responses to electrical resistance for three types of electrodes at moisture contents of 6.3, 6.7, and 9.0 percent, 1965.

Feed Roller Electrode

Resistance readings using the feed roller as the measuring electrode were obtained for 5-, 4-, 3-, 2-, and 1-foot heights of seed cotton above the feeder electrode. Electrical resistance of seed cotton was measured between the insulated feeder roller and a second feeder which was at ground potential. The rollers' outer surfaces were 3 inches apart. Seed cotton pressure against the electrodes resulted from both the weight of seed cotton above rollers and the pressure due to the mass of seed cotton passing between them. Pressure due to seed cotton above electrode roller dropped from 0.13 p.s.i. at feed roller to 0 as the seed cotton level in the hopper bin dropped. The density of cotton passing between the feed rollers was constant at about 5.14 pounds per cubic foot.

Plots of the data collected when cotton was 5 feet deep in the hopper and at 1-foot depth show that signal variation due to changes in cotton depth was virtually eliminated (table 3). These data indicate that an insulated feeder roller electrode might usefully serve as a signal electrode in cotton gin moisture control systems if the electrical design and construction is adequate to prevent excessive electrical leakage.

Multiband Electrode

Experiments with the rotating multiband electrode system were generally satisfactory. A minor feeding problem was caused by cotton slipping against the roller. However, cotton was force fed and rotation was halted three times during the passing of each experimental lot of cotton to measure the electrical resistance at spring tensions of 6, 8, 16, 26, and 40 pounds. These tensions resulted in cotton densities of 11.2, 15.3, 24.5, 27.4, and 30.7 pounds per cubic foot.

In addition to changing the density of cotton, each spring pressure also produced its own effective clearance between electrode and pressure plate of 1.375, 1, 0.625, 0.562, and 0.5 inches, inversely related to pressure.

Seed cotton was in contact with approximately 45 degrees of the electrode circumference resulting in an active signal electrode area of 8.8 square inches. The pressure plate spring tensions used produced cotton pressures of 0.11, 0.14, 0.28, 0.46, and 0.71 p.s.i. of active electrode area.

The principal effect of increasing spring pressure on the plate forcing cotton against the electrode was to shift the instrument response curve (fig. 10). Any of the experimental tensions could probably be used satisfactorily. These data indicate that cotton-to-electrode pressures between 0.2 and 0.5 p.s.i. might be suitable for gin use (fig. 11).

Variations in instrument response caused by variations in seed cotton depth in the feeder hopper were completely eliminated by using the multiband electrode and pressure plate combination.

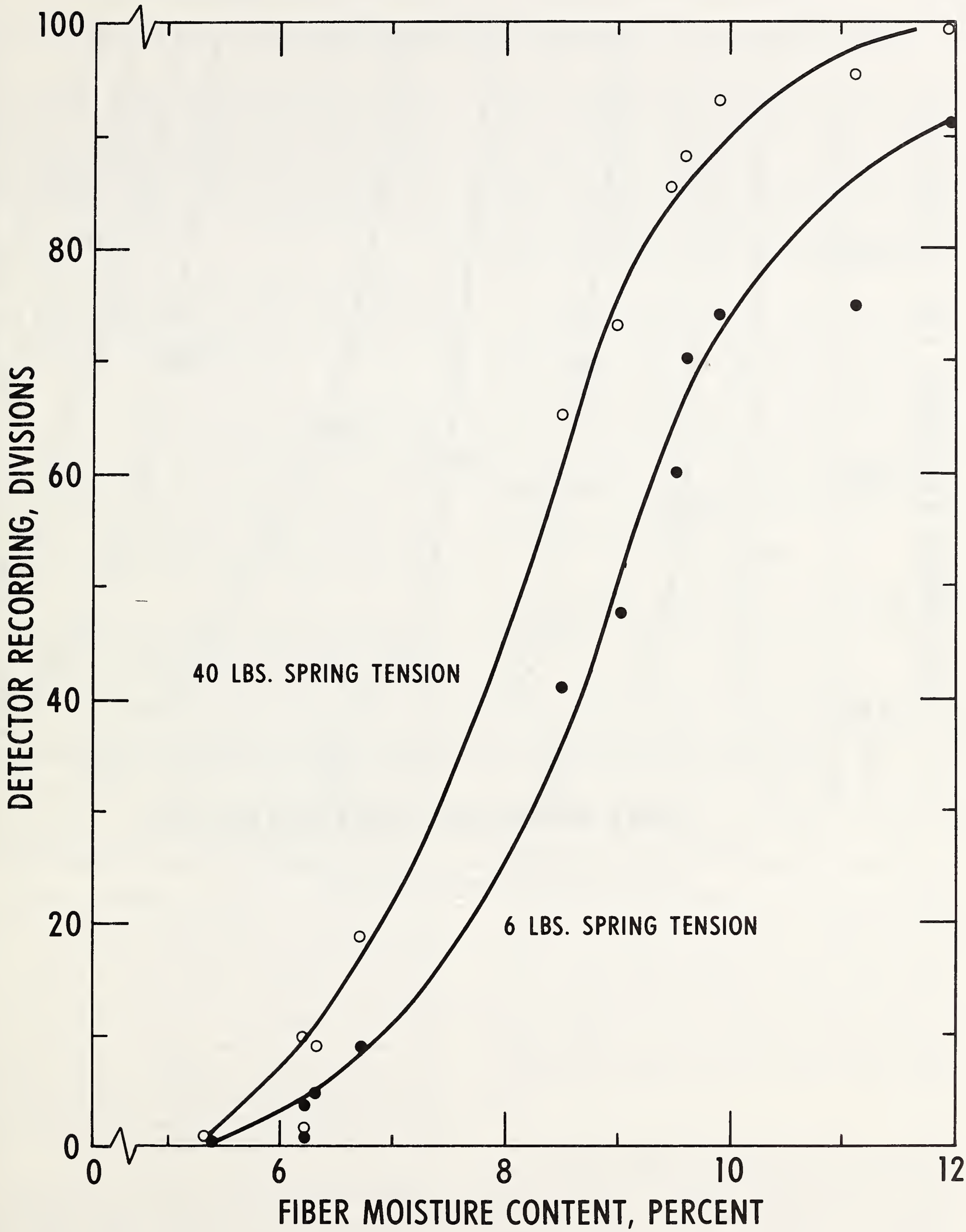

Figure 10.—The effect of pressure plate tension on indicated fiber moisture content using a multiband rotating electrode, 1965 experiments.

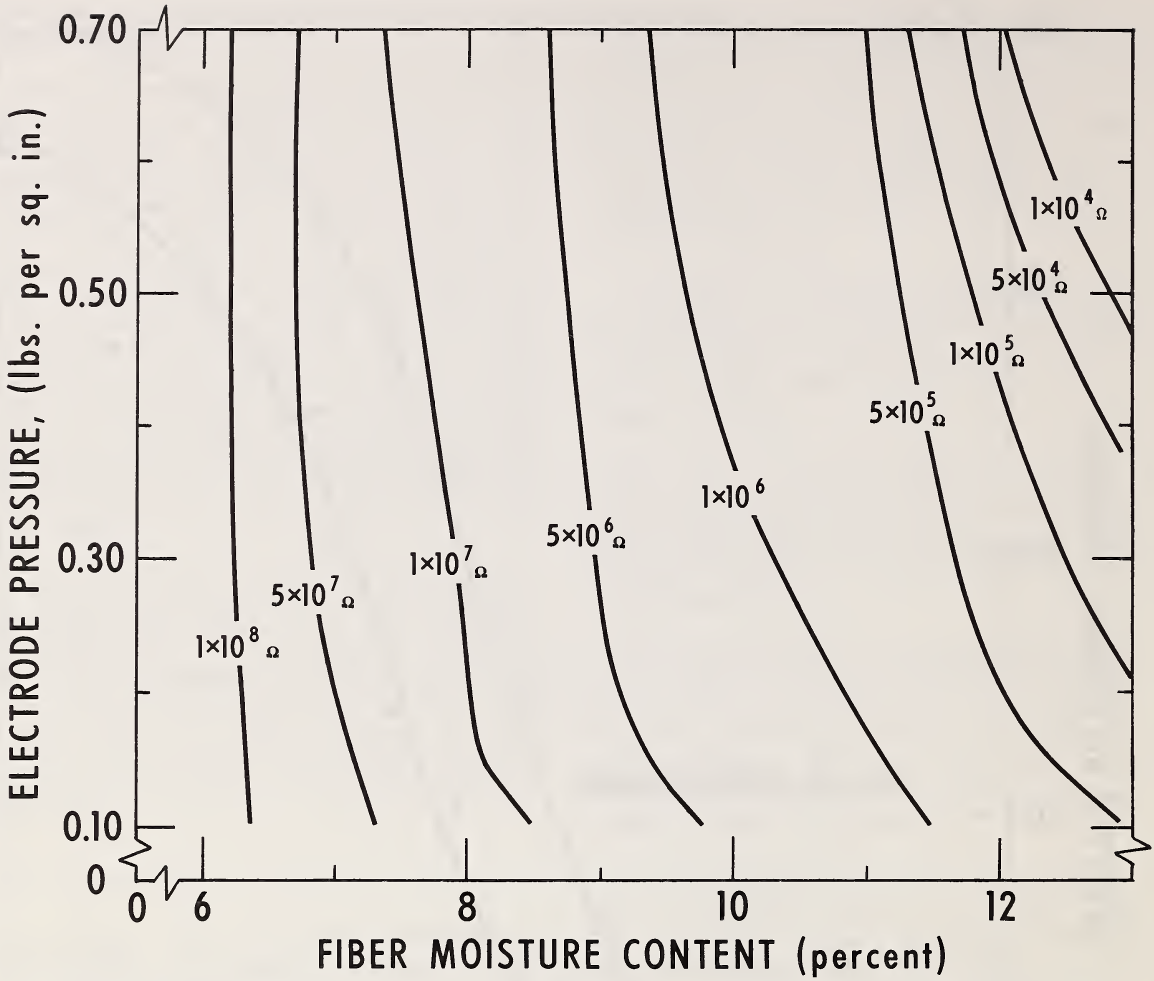

Figure 11.—Resistance obtained for 6 to 13 percent fiber moisture content at varying seed cotton electrode pressure, 1965 experiments. Electrode area was 8.8 square inches.

APPLICATION TO A SYSTEM

In 1960 a recorder was converted to a recorder-controller by adding cam-operated switches to the recording pen positioning motor. The switches operated solenoid pilot valves that controlled the route selection valves of 3-path driers. The cams that operated the switches were set to throw the routing valves at specific fiber moisture contents.

Two experimental studies (1961 and 1962) in which the unit controlled cotton routing through two multipath driers showed that the system was fully capable of automatic control.

The 1961 experiments were directed toward automatic control of seed cotton fiber moisture from two measuring units and to determine the capability of this system. Two commercial moisture detector-recorders, identical in electronic circuitry, were positioned at two stations within the gin plant; namely, feed control No. 1 and feed control No. 2 (fig. 12).

Damp cotton at the input feed controller requiring more than one stage of drying was automatically routed to the first drier, for moisture measurement. It then passed to the second feed control hopper for a second moisture measurement and routing through the finishing drier. Cotton requiring only one stage of drying, or less than a full drier, automatically bypassed the first drier and was routed directly to the second feed controller for routing through all, or part, of the second drier.

The route change valve under the first feed controller routed cotton into the hot air line to drier No. 1 when the detector measured fiber moisture 9.5 percent or more—this corresponds to 90 divisions of the recorder chart scale. A cam-operated switch on the recorder was the primary control element. Cottons containing less than 9.5 percent fiber moisture went via ambient air line directly to the second feed control hopper where the final moisture measurement was made and routed cotton through the 1-, 13-, or 24-shelf drying path of drier No. 2.

Twenty-nine lots were tested. Moisture levels of input fiber ranged from 9.6 to 14.5 percent and of line slide from 5.0 to 6.9 percent, except for one lot which was 7.5 percent. Although the automatic moisture measuring and route selection actions performed excellently, the seed cotton hopper at the second measuring station required close supervision to insure proper cotton flow rate without overflowing. This work revealed that a moisture control system involving only one measuring station in the seed cotton system would be more desirable than a system requiring a second seed cotton moisture measurement to control the second drier.

A modified system in 1962 reduced the measuring system to one feed control unit and one electronic control instrument. All automatic fiber moisture measurement and drier control signals were made from the single unit. An additional modification of the previous system included moving seed cotton to driers with unheated air instead of with heated air. This change considerably reduced the likelihood of overdrying cotton that entered the gin at low moisture content.

The moisture sensing part of the system used spring-loaded, star-shaped feed-roller electrodes located in the master feed control unit.

The objective of the experiment was to deliver seed cotton with fiber moisture at 7-percent level to the gin stand. The electronic controller was set to maintain this level. Two 24-shelf tower driers were employed and total exposure periods could be varied from about 5 to 20 seconds by selecting five combinations of drying paths.

During the 1962 season, 16 lots were ginned under automatic control and were sampled for fiber moisture at the feed control unit at the No. 1 lint cleaner. Initial fiber moisture content varied from 7 to 12 percent and fiber was delivered to the lint cleaner within a 4.5- to 7.3-percent range (table 4). Table 4 shows that the control of moisture content is affected somewhat by the ambient relative humidity.

In a commercial gin, a good practice is to measure the fiber moisture after drying is completed but before ginning. A feedback signal from a second detector would reset the controller, if necessary, making adjustments based on the amount of moisture actually removed and giving more exact control and a closed loop system.

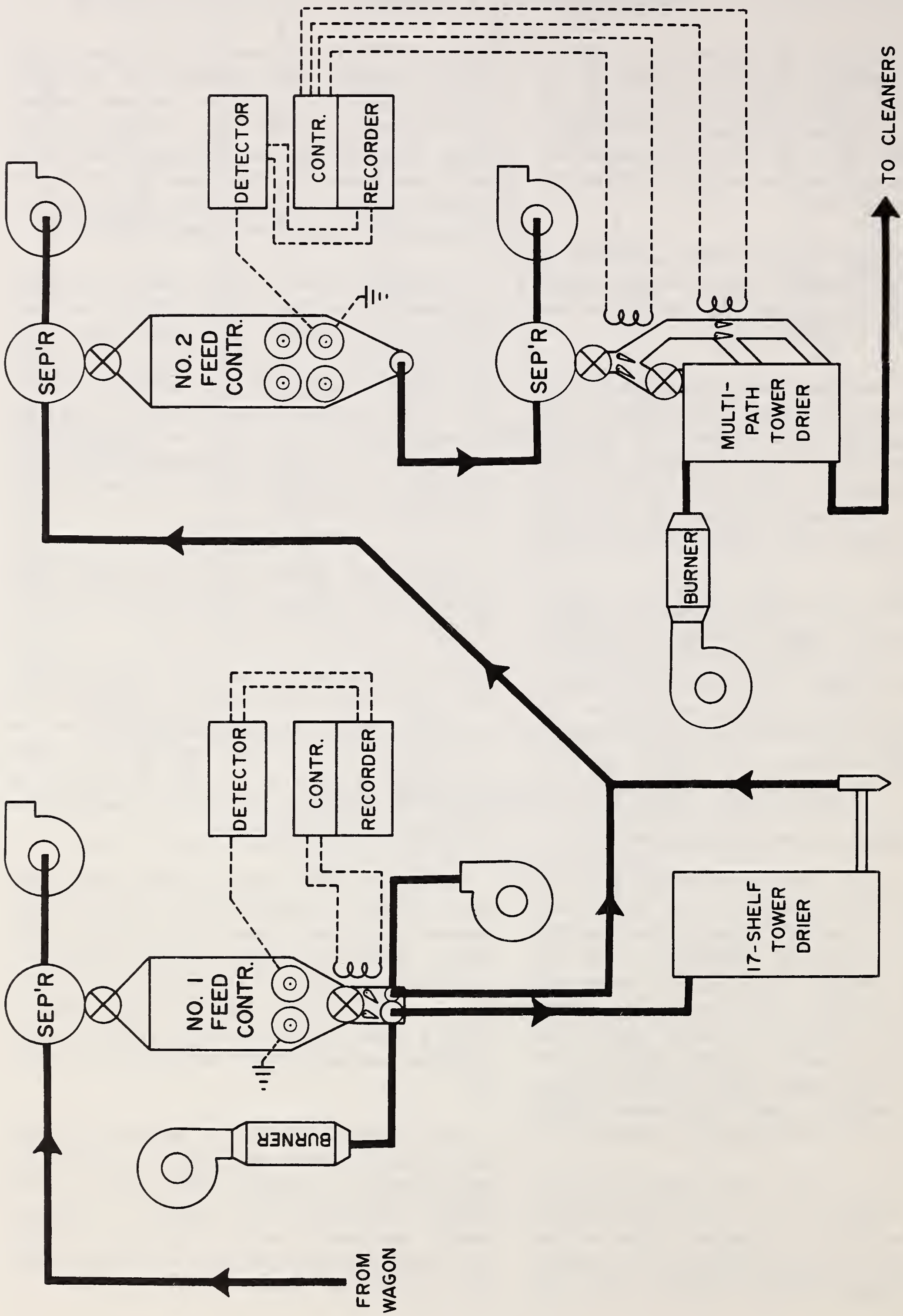

Figure 12.—Automatic seed cotton fiber moisture control from two measuring stations, 1961 experiments.

Because commercial gin drying systems are not standardized, any drying controller operating on a single cotton moisture measurement before cotton enters the drying system must be calibrated after installation in the gin. Length of drying system and variance in air-cotton weight rations are two parameters forcing individual gin calibration.

A measurement made following drying with automatic reset capability would eliminate the need for standardizing the design of drying systems.

The feedback electrode might be located in the seed cotton system in a chute above the distributor, between distributor and gin stand, or a point within the gin stand itself. Locating these electrodes at the lint slide would not control variations in moisture within bales but such a location might be suitable for controlling variation between loads. Experiments have shown that the moisture content of lint can change as much as 2 percent in passing through the lint cleaning and lint flue system. Thus, a measuring unit at the lint slide station could give a feedback signal not based on the actual fiber moisture content at ginning. The station located after seed cotton drying and cleaning, but before ginning, would more nearly give the proper fiber moisture reading.

SUMMARY AND CONCLUSIONS

From 1954 to 1965, experimental studies were conducted by the U.S. Cotton Ginning Research Laboratory, Stoneville, Miss., to investigate and design electrodes that might be used at gins with automatic moisture control systems. These electrodes provide the means whereby the fiber moisture control instruments measure the electrical resistance of seed cotton or lint as a function of moisture content.

Factors other than fiber moisture content also affect the response of resistance measuring instruments. Some of these factors were examined to determine the nature and extent of their effect on the measuring system. They were as follows:

1. Electrode area.
2. Electrical leakage paths due to electrode fouling.
3. Location of measuring electrodes along the cotton processing route.
4. Density and pressure of cotton under measurement.

A definite relationship existed between fiber mass electrical resistance and mass density. Variations in density will affect resistance based moisture sensors sufficiently that gin-drying systems using the resistance measuring principle should be calibrated at and for a specific cotton mass density, and provisions should be made to maintain that density for proper operation of the system.

Studies covering a fiber moisture range from 4.5 to 17.4 percent showed a practical electrical resistance range of cotton normally encountered at a gin plant to vary from 30,000 ohms to 1,000 megohms when measured with rotating-type electrodes. With seed cotton exerting a pressure of 0.1 to 0.7 p.s.i. against electrodes, moisture, seed cotton density, and electrical resistance relationships were established. The data indicated that cotton-to-electrode pressures of 0.2 to 0.5 p.s.i. should be suitable for gin use.

Decreases in resistance when employing large electrode areas were found not attributable to area alone. Electrical current flow seeks the path of least resistance and the resistance measured is that of the dampest cotton. The greater the electrode area, the greater the chance of including damp cotton in the measurement. Large electrode areas could easily lead to overdrying. Overdrying will more likely be prevented if small electrode areas with the proper amount of pressure is employed. Calibration of electrode systems in gin plants to prevent overdrying cannot be overemphasized.

Investigations using flat plate or stationary rod electrodes inside the feed control hopper showed that they were unsuitable as measuring electrodes because cotton density variations gave unwanted calibration shifts.

The insulated feeder roller electrode and the Department's multiband rotating electrode operating against a constant cotton pressure provided a more reliable response from the detector circuit.

Although the feeder rollers provided very good results as moisture-measuring electrodes, electrical leakage at the bearing locations poses a problem for long-term trouble free use.

An excellent constant pressure electrode system would result from incorporating a multiband section in conventional feeder rollers and using the Department's end-of-shaft scheme for signal takeoff. This combination combines the best features of both feeder roller and multiband electrodes.

This electrode system employs a relatively small electrode area tending to measure the cotton's average moisture content instead of always responding to the dampest part of the cotton as a full width electrode. The alternate band pattern is preferred over the all metal star-shaped electrodes because of its superior insulating design, which reduces the current leakage problem.

An electrode of the same configuration as conventional feed rollers but mounted as a separate insulated section in the center of the feed roller would give results comparable to the multiband system. Signal takeoff would be by the end-of-shaft scheme.

Automatic moisture measurement and control studies were performed in a three-stand commercial-type ginnery employing the feed roller and parallel-band (multiband) electrodes with laboratory-built and commercially available detector-controllers. Results of this work revealed that two moisture-measuring stations before completed drying are not required for automatic drier control. One detector-controller located at the master feed control unit and controlling the cotton exposure period through two tower driers gave results comparable to two detector-controller units, one located at the master feed control station and controlling the first tower drier and the second unit located after the first drier and controlling a second tower drier.

A closed loop control system is required for more precise moisture control. This system would be controlled from one measuring station, preferably at the master feed rate controller, followed by a feedback measurement station located after completed drying but before fiber-seed separation in the gin stand. The feedback device would provide a reset measurement to master moisture recorder-controller and would, to a great extent, overcome the need for standardizing the design of drying systems.

APPENDIX

TABLE 1.—Effect of length of rod electrode and density of seed cotton on electrical resistance of seed cotton at 10.8 percent fiber moisture content, 1959

Length of electrode (inches)	Seed cotton density per cubic foot	Resistance
	Pounds	*Divisions*[1]
2	4.96	81.0
4	4.96	86.0
6	4.96	89.7
8	4.96	91.0
10	2.85	86.0
10	3.46	87.5
10	4.42	90.0
10	5.52	91.3
10	6.70	92.0

[1] Arbitrary units. An increase in units indicates a decrease in electrical resistance.

TABLE 2.—Instrument response when using a flat plate electrode in hopper to indicate moisture content of cotton at depths of 4.5 feet and 1 foot, 1965

Fiber moisture content (percent)	Pen deflection	
	4.5 feet	1 foot
	Divisions	*Divisions*
6.2	1	0
6.2	3	4
6.3	3	2
6.7	1	4
8.5	23	21
9.0	46	30
9.5	65	53
9.6	48	66
9.9	95	81
11.1	53	61
12.0	91	88

TABLE 3.—Instrument response when using standard feed rollers as an electrode system to indicate moisture content of cotton at depths of 5 feet and 1 foot, 1965 experiments

Fiber moisture content (percent)	Pen deflection	
	5 feet	1 foot
	Divisions	*Divisions*
6.2	2	3
6.2	8	9
6.3	5	7
6.7	7	9
8.5	46	51
9.0	61	60
9.5	72	72
9.6	88	85
9.9	91	91
11.1	88	91
12.0	93	97

TABLE 4.—Fiber moisture obtained by automatic control of drying period[1]

Ambient air		Fiber moisture content[2]	
Temperature (°F.)	Relative humidity	Before drying	After drying
	Percent	*Percent*	*Percent*
86	60	12.0	7.3
85	63	11.6	6.7
57	61	11.6	6.5
75	66	9.0	6.0
75	66	8.9	5.9
54	47	9.1	5.8
58	61	10.9	5.7
86	47	7.6	5.5
87	45	8.0	5.4
54	47	8.9	5.1
57	45	7.0	5.0
74	40	8.4	4.9
58	42	7.5	4.9
55	44	8.4	4.8
73	39	7.9	4.7
74	37	8.1	4.5

[1] 5 drying exposure periods of 4.8 to 20.2 seconds selected by controller. Air temperature at top of tower drier maintained at 200° F.

[2] Average of 12 samples.

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